From Individuals to Populations: Modeling Aquatic Toxicity Data Across Levels of Biological Organization

Sandy Raimondo and Charles L. McKenney, Jr.
USEPA/ORD/NHEERL/GED

Environmental Issue

- The Office of Prevention, Pesticides, and Toxic Substances (OPPTS) requires efficient methods to evaluate the ecological effects of thousands of chemicals.

- Ecological risk needs to incorporate population-level response of organisms exposed to toxicants.

- Matrix population models provide a tool for determining population effects from traditional toxicity data.

Americamysis bahia is standard EPA estuarine test organism

Scientific Approach

- Stage-structured matrix models were developed from complete life-cycle tests of the mysid (*Americamysis bahia*) exposed to 5 to 6 test solutions of 6 toxicants.

$$A = \begin{pmatrix} 0 & 0 & 0 & 0 & F_5 & F_6 & F_7 \\ G_1 & P_2 & 0 & 0 & 0 & 0 & 0 \\ 0 & G_2 & P_3 & 0 & 0 & 0 & 0 \\ 0 & 0 & G_3 & P_4 & 0 & 0 & 0 \\ 0 & 0 & 0 & G_4 & P_5 & 0 & 0 \\ 0 & 0 & 0 & 0 & G_5 & P_6 & 0 \\ 0 & 0 & 0 & 0 & 0 & G_6 & P_7 \end{pmatrix} \qquad N_{t+1} = AN_t$$

Seven stage transition matrix, A, composed of the probability of surviving within a stage, P_i, probability of transitioning within a stage, G_i, and the reproductive output of females within a stage, F_i.

- Toxicity test endpoints were compared to population growth rate, λ, obtained from matrix models.

Individuals to Population Synthesis

Individual-level effects
- no effect
- delayed reproduction
- reduced overall reproduction
- reduced overall reproduction and reduced survival

	Test Solution					
	1	2	3	4	5	6
Endosulfan		DR	DR	R S	R S	
DEF	DR	DR	DR	R S	R S	
Fenthion			DR	R	R S	
Thiobencarb			R	R	R S	R S
Methoprene				R	R	R S
Silver Nitrate	DR	R	R	R	R S	

- (gray) = no observable effect (NOEC)
- **R** (yellow) = overall reproduction reduced
- **DR** (green) = delayed reproduction
- **RS** (purple) = survival and reproductive effects

Population growth rate for each individual-level response found that not all individual-level responses result in a significantly reduced population growth rate
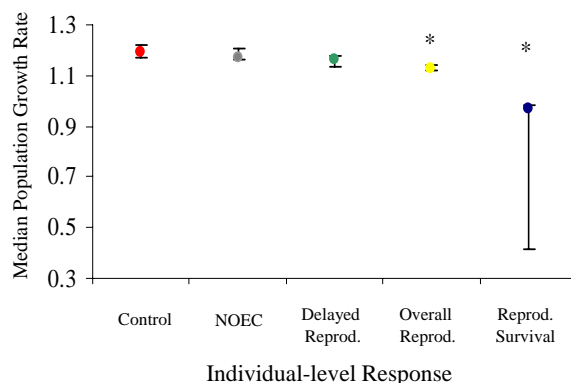
Median population growth rate modeled of toxicant concentrations resulting in each individual-level response (*Kruskal-Wallis, $P<0.05$).

Conclusion:

Population models link traditional toxicity approaches and need for population-level assessment